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Risk factors analysis and countermeasures of FPSO's lightering in Dongying sea area

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RISK FACTORS ANALYSIS AND COUNTERMEASUERS OF FPSO'S LIGHTERING IN DONGYING SEA AREA

By

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Research Paper: **Risk Factors Analysis and Countermeasures of FPSO's Lightering in Dong Ying Sea Area**

Degree: **Msc**

This paper first analyzes the concept and evolution of FPSO, the common ways of lightering of FPSO, the supervision of maritime authority on FPSO's lightering. Secondly, it identifies risk factors of the FPSO's lightering operation, and conducts a qualitative evaluation. Then, in combination with practical working experience and the opinion of operation personnel, utilizing the theory of ship maneuvering and sailing experience, it puts forward the restricted conditions of FPSO's lightering of Dong Ying prefecture, optimizing the operational plan of the FPSO's lightering; Finally, it puts forward regulatory suggestions according to current situation of supervision.

Through the study of two FPSO lightering operating procedure in Dong Ying sea area, it standardizes the procedure of FPSO lightering operation, solve the shortage and controversy caused by multi-aspect management, insufficient knowledge and do not have a unified standard; Make up for the lack of maritime regulation in FPSO field, reduce the risk of FPSO lightering; enrich the understanding of the risk of FPSO lightering operation and the FPSO lightering theory to a certain extent, provide ideas for maritime supervision of FPSO lightering operation, and comprehensive protection against operating risk.

Keywords: FPSO; Dong Ying sea area; Lightering operation; Maritime supervision

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LIST OF ABBREVIATIONS

BZ	Bo Zhong
CCR	Center Control Room
CNOOC	China National Offshore Oil Corp
FPSO	Floating production, Storage and Offloading
ICLL	The International Convention on Load Lines
IMO	International Maritime Orgnization
MPEC	Maritime Prevention Environment Committee
MORPOL	International Convention for the Prevention of Pollution from Ships
MSA	Maritime Safety Administration
MSC	Maritime Safety Committee
NOTAMS	Notices to Airmen
SPM	Single Point Mooring
SOLAS	International Convention for the Safety of Life at Sea

Chapter 1 Introduction

1.1 Background of research

1.1.1 Concept of FPSO

FPSO is the abbreviation of oil floating production storage and offloading unit, which is an organic whole of production, storage, transmission and life, power (some with no power), the largest monomer of ocean petroleum investment project, used to process and store crude oil. Lifting vessels will arrival on a regular basis, and unloading crude oil and sent it around the world. The operation principle is: receiving the crude oil of extraction from the well through the submarine pipeline, and processing it in the tanker, then storing it in the cargo oil tankers, and then transport it to lifting vessels by unloading system. as offshore oil production facilities, FPSO system can give full play to its functional features in deep sea and area where offshore oil pipeline is not developed .（CNOOC, 2010）*FPSO mainly includes the following parts:*

1. The single-point mooring system: this system can have one or more anchors, a root or more vertical tube, a floating or fixed buoy, a turret or skeleton, mainly used for the FPSO mooring in operation oil field.

2. The hull part: this part can be new construction according to the specific requirements, or also can be re-equipped by oil tanker or barge.

3. Production equipment: mainly oil production equipment and storage equipment, and oil, gas, water separation equipment.

4. Unloading system: including warping winch, hose reel, etc., used to connect and fix lifting vessels, and discharge the crude oil in FPSO into the shuttle tanker. (

Abstract of Waterway Transport,2003)

(As shown in figure 1- 1)

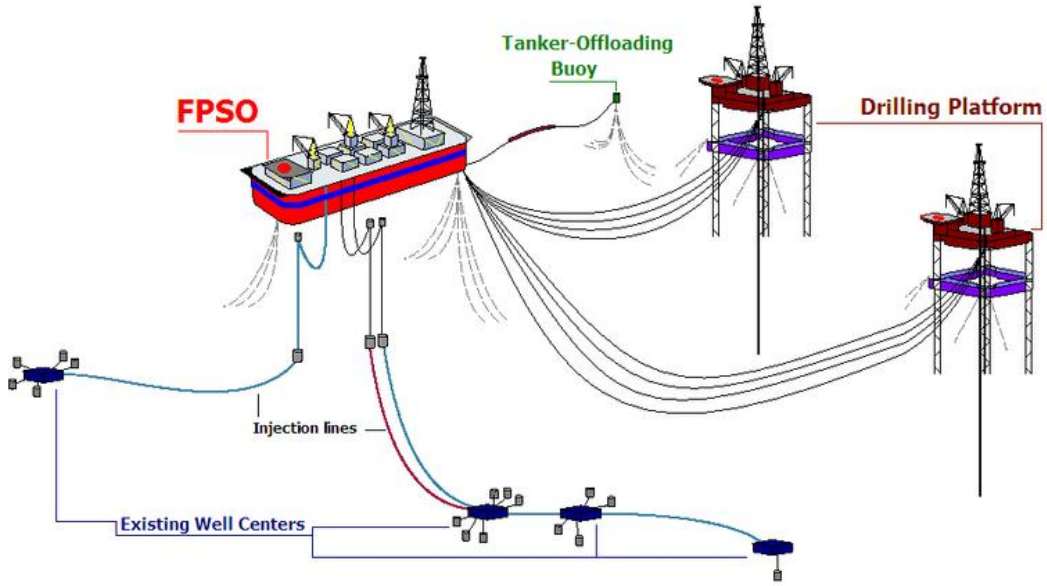


Figure 1.-1 Arrangement of FPSO

Source: Ma, X L (2010). Risk identification and analysis of oil spill of FPSO. Bacheloral dissertation of Dalian maritime university,p2.

1.1.2 FPSO's development progress and the development and status quo of FPSO in China

From the late seventies to now, the development of FPSO has experience " three times wave".

(1) From 1977 to 1985: FPSO appeared and became one of the options of floating production system. In August 1977, a commercial tanker refitted into a FPSO by the Spanish shell for the first time.

(2) From 1986 to 1994: technology developed rapidly during this period, the application of FPSO's expanded to a wider geographical scope, its production was bigger, and used in deeper water. At this stage, about two would be arranged each year on average.

(3) Since 1995, it was a period of explosive growth of FPSO.

(Ma, 2008, p3)

So far, there are more than one hundred FPSOs in the world, mainly distributed in the

north sea, Brazil's coast, west Africa, southeast Asia and China. FPSO's tonnage has developed from thousands of tons in the early days to more than 40 thousand tons today. Nowadays, FPSO has gradually got rid of the Ship concept and turned toward the direction of ocean engineering. As the need of development of small or medium-sized and marginal oilfield, a variety of FPSO have appeared, such as: small tonnage and compact FPSO; In order to adapt to the application of multi-point mooring system, non-hull Ship design has been adopted; The concept of deep sea mooring design; LPG and LNG offshore floating production storage system.

As the pace of offshore oil development speeds up, the number of FPSO also has a growth in China. At present China has become one of country who has the most new constructed FPSO in the world. CNOOC is the only company who applies FPSO in china currently, in 1986, "Nan Hai Xi Wang" –FPSO has been adopted for oil exploitation in Bei Hai Gulf in 1986 for the first time. Now not only free floating production system has used in Bei Hai sea, and it has been used in south china sea where has always been attacked by typhoon and sea condition is poor, FPSO has a tendency to replace fixed production platform.

Some related aspects of the research of FPSO are being carried out in some research institutes in china, such as 708 research institute of CSSC, Shang Hai Jiao Tong University and other units; ShangHai Hudong Zhong Hua Shipbuilding group has set up a post-doctoral mobile stations for FPSO project; Dong Ying Sheng Li oilfield is working on the research of small FPSO.

Table 1-1 FPSO’s general situation in china

Name	Load Quality/t	Way of Mooring	Oilfield
BoHaiYouYi	$5.5x10^4$	Mild Steel Arm type	BZ28-1oilfield
HaiYangShiYou102	$5.2x10^4$	Mild Steel Arm	BZ28-2oilfield

		type	
Bo Hai Shi Ji	$15.0X10^4$	Mild Steel Arm type	BZ34-2oilfiel
Nan Hai Fa Xian	$23.0X10^4$	Turret type	Qinghuangdao32-6oilfiedl
Nan Hai Kai Tuo	$15.0X10^4$	Turret type	HuiZhou21-1oilfield
Nan Hai Mu Ning	$9.0X10^4$	Turret type	LuFeng22-1oilfield
HaiYangShiYou111	$15.0X10^4$	Turret type	LuFeng22-1oilfield
HaiYangShiYou112	$16.0X10^4$	Turret type	PanYu4-2oilfield
HaiYangShiYou113	$16.5X10^4$	Mild Steel Arm type	BZ25-1oilfield
HaiYangShiYou115	$10.0X10^4$	Turret type	Nan Hai oilfield
HaiYangShiYou116	$10.0X10^4$	Turret type	Wen Chang oilfield
HaiYangShiYou117	$30.0X10^4$	Mild Steel Arm type	Penglai19-3oilfield

Source: Shan L Z, Dong B J, Liu M（2008）. Technology Status Quo and Development Trend of FPSO, Oil Field Equipment, V37, 21,p28.

1.2 FPSO connection way

FPSO usually adopts the single point mooring so as to achieve the aim of obtaining smaller mooring force, FPSO connection of single point mooring as shown in figure 1-2.

Figure 1-2 FPSO connection of single point mooring

Source: China National Offshore oil Corporation Tianjing company(2010), The Introduction of FPSO. Unpublished PPT, Tianjing, China.

1.3 FPSO lightering operation

In the process of lightering, FPSO is equivalent to terminal, usually have two ways: side by is consistent with berthing in port, FPSO acts as the role of the fixed terminal, shuttle tanker berth in one side of FPSO, their movements are not synchronized, when the wind and wave are bigger, the risk happens. In the accident, consequence is unimaginable. This way of lightering has been less and less.

Figure 1-3 and by way of “Bo Hai Ming Zhu”

Source: China National offshore oil Corporation Tianjing company(2010), The Introduction of FPSO. Unpublished PPT , Tianjing, China.

Stern by (series): shuttle tanker connects the stern of FPSO through cable, stays in straight line with FPSO. This way can adapt to operation under worse sea condition, and lifting vessel can liberate rope more safer and more convenient. It has small impact on the single point mooring, at present most of FPSO’s lightering adopting this way. FPSO lightering process of tail way usually needs two support vessels. Before the lightering operations, shuttle tanker slows approaching the stern of FPSO, and maintains a safe distance; Then it fastens mooring cable by tug, and plugs the oil hoses; One assisting tug drags the stern of shuttle tanker to keep heading aligned with the FPSO orientation, then begins operation of lightering; after the operation, it liberate the hose, frees the cable.(Wu, 2007)

Figure 1-4 Hai Yang Shi You 102

Source: China National offshore oil Corporation Tianjing company(2010), The Introduction of FPSO. Unpublished PPT, Tianjing, China.

1.4 Purpose of research

By studying the characteristics of existing FPSO lightering operation in Dong Ying sea area, combined with the weather and condition of the sea, considering human life, property, environmental factors, safety and economic benefits in lightering comprehensively, this paper evaluates the operation risk of FPSO's lightering, defines the limitation of FPSO lightering operation in the Dong Ying sea area, optimizes the scheme of operation, and provides the reference for the safety of FPSO lightering operation.

The study will have certain sense on standardizing the procedures of FPSO's lightering operation, solve the shortage and controversy caused by multi-aspect

management, insufficient knowledge and no unified standard; enrich the understanding of the risk of FPSO lightering operation and the FPSO lightering theory to a certain extent, provide ideas for maritime supervision of FPSO lightering operation, and comprehensive protection against operating risk, make up for the lack of maritime regulation in FPSO field, reduce the risk of FPSO lightering, and protect the property of ship, safety of human life and the Marine environment from pollution; The research will to some extent enrich the understanding of the risk of FPSO lightering operation and the theory of the FPSO lightering to some extent, and provide ideas for maritime supervision of FPSO lightering operation, and comprehensive protection against operating risk.

1.5 Content of research

1.5.1 The main content of research

(1) The status quo analysis of FPSO lightering operation and maritime regulatory in Dong Ying sea area;

(2) Risk factors identification and assessment of FPSO lightering in Dong Ying sea area;

(3) Restrictions research of FPSO lightering in Dong Ying sea area;

(4) Optimization of FPSO lightering operation.

1.5.2 Key problems proposed to solve

(1) Risk factors identification and qualitative evaluation of FPSO lightering operation in Dong Ying sea area;

(2) Formulation of constrains of FPSO lightering operation in Dong Ying sea area;

Chapter 2 The Status Quo of FPSO's Lightering Operation in Dong Ying Sea area

This chapter mainly introduces the existing distribution of oilfield and FPSO in Dong Ying sea area.

2.1 Oilfield distribution in Dong Ying sea area

2.1.1 Oilfield distribution in Bo Hai sea

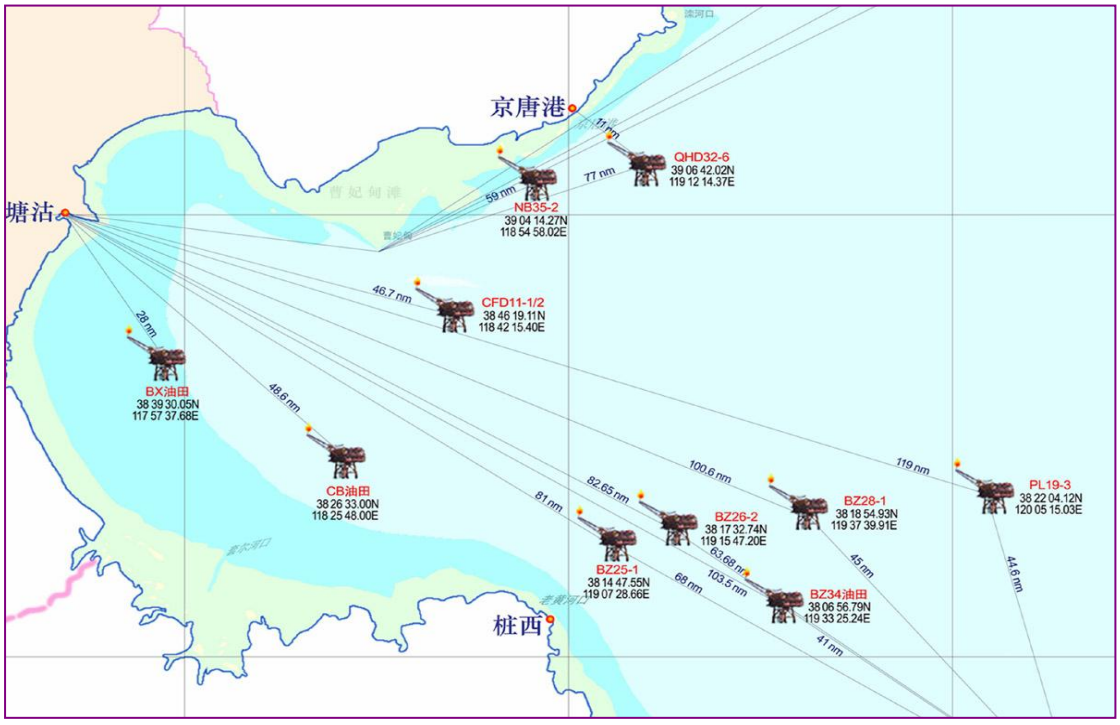


Figure 2-1 Oilfield distribution in Bo Hai sea

Source: China National Offshore oil Corporation Tianjing company(2010), The introduction of FPSO. Unpublished PPT, Tianjing, China.

2.1.2 Oilfield distribution in Dong Ying sea area

Dong Ying sea area is the main production area of oil resources, include: Sheng Li Cheng Dao Oilfield, Sheng Li Xin Bei Oilfield, 25-1, 28-2 Oilfild in Bo Hai sea, Ken Li 3-2 Oilfield, Sheng Li Qing dong Oilfield.

Among them, 25-1 and 28-2 oilfield belong to CNOOC, each region having a FPSO, respectively "HaiYang Shi You113" and "Hai Yang Shi You102", Both adopting the way of single point mooring, and storage capacity are 52920 m^3 and 52920 m^3 respectively, the average lightering operation frequency is 5 days/time, around 145 times one year, and output about 4.5 million tons of crude oil.

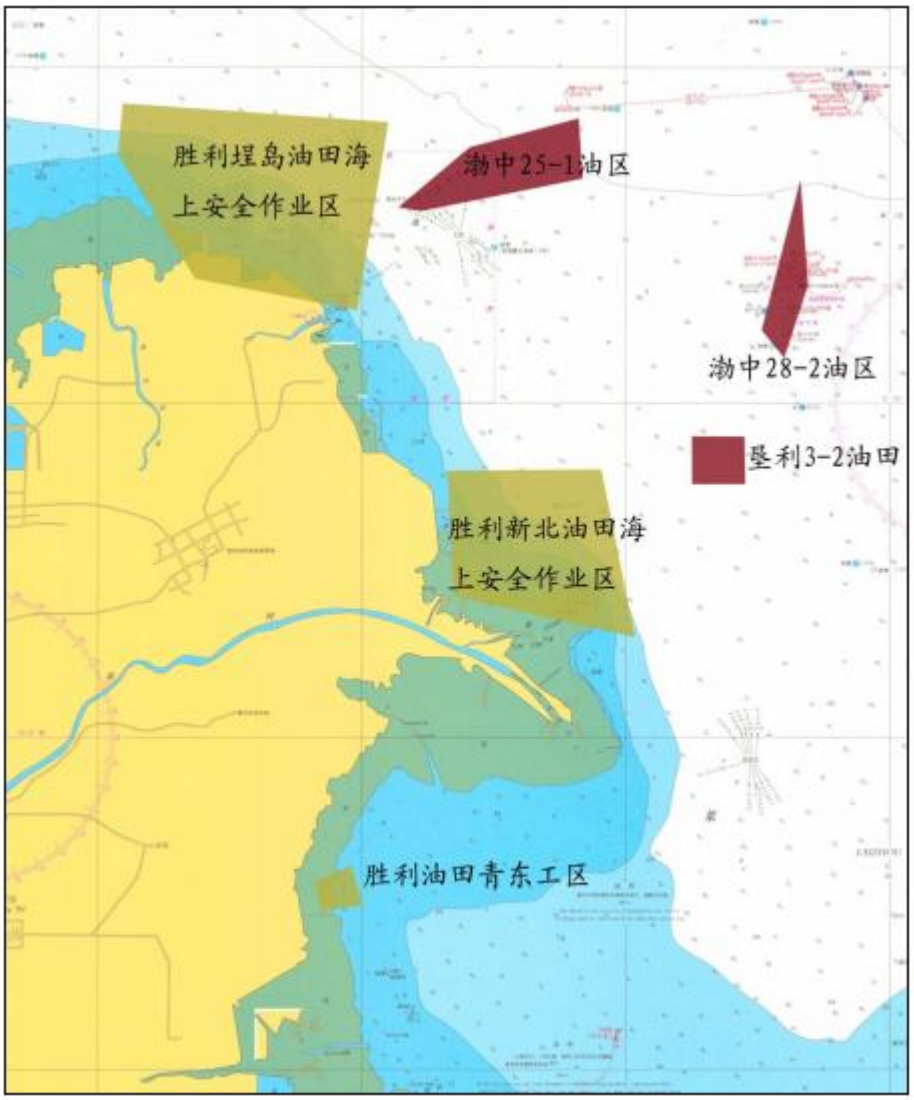


Figure 2-2 Oilfield distribution in Dong Ying sea area

Source: Dong Ying MSA

2.2 FPSO distribution in Dong Ying sea area

At present, two FPSO are in Dong Ying sea jurisdiction, shown in Table 2.1-1.

Table 2-1 FPSO's distribution in Dong Ying Sea area

FPSO	Oilfield	Location of SPM	Load displacement(T)	Maximum unload rate（m^3/h）	Maximum storage capacity（barrel）	Tanker size limitation
Hai Yang Shi You102	BZ28-2	38°13′37.476″N 119°33′15.620″E	68125	3000	372000	15000-110000 GT
Hai Yang Shi You113	BZ25-1	38°14′04.869″N 119°08′56.186″E	160042	6000	973300	40000-120000 GT

Source: Compiled by Author

Figure 2-2 Hai Yang Shi You 102

Source: China National offshore oil Corporation Tianjing company(2010), The Introduction of FPSO. Unpublished PPT, Tianjing, China.

"Hai Yang Shi You102" is a FPSO, load displacement being 68125 tons. FPSO mooring in a fixed mooring tower,two parts connected with flexible connection mode. In severe ice or other abnormal condition, FPSO can be released from the mooring tower, and be towed to a safe area. Before the FPSO is freed, soft rock needs to be unloaded, so that it can float. The other side of soft rocker is retained on the fixed mooring tower. Some devices of production, storage, metering of crude oil are equipped on FPSO.(CNOOC,2009)

Figure 2-3 Hai Yang Shi You 113

Source: China National offshore oil Corporation Tianjing company(2010), The Introduction of FPSO. Unpublished PPT, Tianjing, China.

The 160,042 Tonnes deadweight tanker "Hai Yang Shi You 113" is a Floating Production Storage and Offloading (FPSO) Unit. The Terminal is semi-permanently moored by a Tower Yoke type Single Point Mooring (SPM). In the event of severe ice or other abnormal conditions, the Terminal may be disconnected from the SPM and towed to a sheltered location. Before the Terminal is towed away, the fluid and power jumpers will be disconnected and recovered onto the Terminal, and the yoke will be disconnected and lowered to the seabed

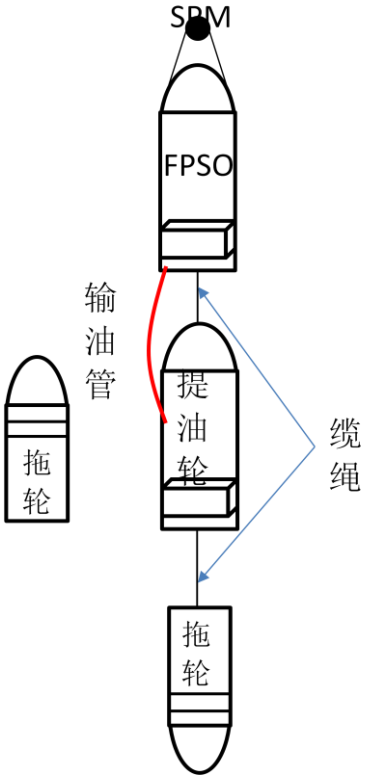
A lifting vessel loading crude oil from the BZ Unit Area will be berthed by a single mooring hawser and 76mm chain connected from the stern of the FPSO to the lifting vessel's forward 76mm chain stopper in a "tandem Moor'.

Crude oil is loaded through a floating hose assembly from the stern of the FPSO to the lifting vessel's starboard midship manifold. One 16 inch connection must be available on the lifting vessel for this purpose（CNOOC,2012）

2.3 Lightering operation in oilfield

2.3.1 Lightering operation mode of "Hai Yang Shi You 102" and "Hai Yang Shi You 113"

As illustrated in the figure of ligterting operation, For the small-keyBoard of transmission mode, red cruve represents oil hose, assisting tug on the left side of the tanker, responsible for transmit cable, oil hose, etc. During operation, tail tug drags the stern of the shuttle tanker and keeps the tanker and FPSO in a safe distance and in line with each other.



During operation, FPSO, shuttle tanker and tug move around SPM during operation according to the variation of tide.

Prior to the transportation, shuttle tanker drives to the stern of FPSO slowly and keeps a safe distance, at the same time, the tail tug connects cable to the stern of shuttle tanker and keeps oil tanker controllable, then another tug assist to fasten connecting cable between FPSO and tanker, tail tug would keep heading of tanker and orientation of FPSO in relatively stable during whole process. After plugging in the oil hose, transportation begins. Following the transportation, freeing the hose and table, shuttle tanker leaves the FPSO.(Case report of "Hai Yang Shi YOU 102"(2012) . Dong Ying MSA ,p4)

Figure 2-4 lightering of string by

Source: Case report of "Hai Yang Shi You 102"(2012). Dong Ying MSA, p2

2.3.2 Safety zone of lightering operation

Security area has usually been set around FPSO's lightering operation areas (500m outside the Ship line extension of lightering operation), and alert area or navigation control area have always been set up according to the need (2 nmiles of Ship line extension of lightering operation), published in the form of NOTAMS.

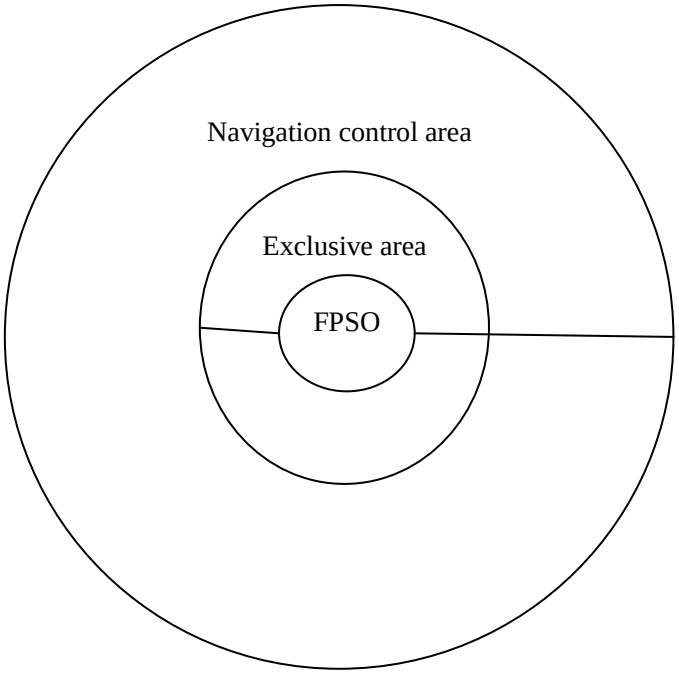


Figure 2-5 Security areas of FPSO lightering operation

Source: Compiled by author

Passing vessel should avoid sailing into navigation control area of FPSO's lightering area as far as possible. It is forbidden to enter security areas of lightering operation. If a ship wants to enter into navigation control area, it must report to Dong Ying VTS and obey the command of the control center. Ships in the navigation control areas are prohibited to encounter, overtaking or anchoring in navigation area, and should control the speed appropriately. When ship plans the route in the waters, it should try to keep outside the FPSO navigation control area.

2.4 Problems of FPSO lightering operation

FPSO's lightering operation in China started in 1980s, with the rise of FPSO and large scale of lifting vessel. The problem related with it increased sharply.

Relevant laws and regulations have made rules on the relevant problem of lightering operation, and maritime department have also accumulated many experiences. The problems of FPSO are listed as follows:

2.4.1 Inadequate understanding of lightering operation risk, lightering operation risk is big

Lack of awareness of the risk of lightering operations, there is a big risk for lightering operation. Due to the complicity of marine environment, many vessel and personnel involved in lightering operation are likely to have accidents like fire, collision, explosion, oil spills, etc in the process of lightering operation. Once an accident happens, not only will it cause huge economic losses, but also pollutes the environment. With the increase in production of oil at sea, large scale of lifting vessel, FPSO and increasingly frequent of lightering operations, lightering risk is greater.

2.4.2 Lack of systematic assessment of operational risk

Lightering operation is a very complex, very systematic course, it need the cooperation of oilfield, marine department, pilot , support vessel, lifting vessel, commodity inspection department etc to complete and affected by weather, equipment, personnel quality and other factors, at present, it lack of systematic assessment of the operational risk .

2.4.3 Lack of appropriate security practices

At present, the legal status of China's FPSO is explicit according to the existing law system, resulting in lack of legal basis, management requirement not matching the regulatory measures on the FPSO’s supervision. At present, technical regulation of FPSO is referred by the competent authority of maritime on surveillance, but the technical standard is not unified in different FPSO, and no unified standards accepted by different parties; and in the production process of FPSO involving multiple departments like commodity inspection department, shipping companies, tug company, oilfield company, pilot station and maritime department, each sector has

their own requirement and understanding on the lightering operations, which have a lot of subjective factors that affect the lightering operation, and seriously affect the security of lightering.

2.4.4 Emergency response force is weak and emergency response mechanism is inadequate

Maritime emergency force is not enough, emergency response plan of lightering operation is incomplete. At present, once oil leaks out in lightering only oilfield itself can carry out relief work as the location is far away from the shore, both maritime department and social forces are unable to meet the needs of offshore oil clean-up.（Wang, 2007,p39）

Chapter 3 International Conventions on the FPSO and the Status Quo of Surveillance on FPSO of China

3.1 Requirement of international convention on FPSO

In recent years, FPSO is an issue always been discussed by MARPOL, SOLAS, ICLL, STCW etc conventions of IMO. Marine Environment Protection Committee (MEPC) is responsible for the research problem of application of MARPOL on FPSO, and specifies the Board of BLG responsible for the FPSO project. Maritime safety committee (MSC) is responsible for the research of application of SOLAS, load line convention on FPSO.

3.1.1 Requirement of MARPOL convention on FPSO

FPSO and FSU Application Guide for MARPOL Annex I requirements(MEPC/Circ. 406) has been issued by MEPC in the form of circular. So far, the revised MEPC/Circ. 406 is the specific file of MARPOL Annex I for the FPSO. MEPC49 illustrates the specific content of the above terms, and stresses the set, function, operation of the FPSO under the supervision of coastal states. That is to say, the content of the "guide" above mentioned is not mandatory on the effectiveness, for the terms of the word "advice" in the “guide”, MEPC recommends that governments refer to the implementation.

Nonetheless, with the speeding up of utilization and development of the marine resources by human, the growth of number of offshore mobile platform and FPSO, the increase of the threat to the Marine environment is increasing. It is a trend that management will be mandatory by IMO in the future. Through research and analysis, the following conclusions can be concluded:

1 FPSO in run is a form of fixed or floating platform, within the scope of the definition of the Ship under MARPOL convention, and out of the scope of the definition of tanker under MARPOL Annex I. For FPSO of self-propelled capacity, when it is in navigation status, it is a tanker of full sense.

2 The FPSO is fixed or floating platform, it should be restricted as a fixed or floating platform by the terms of MARPOL Annex I. When the FPSO is fixed on the work site, including detach from worksite short and safely under extreme natural environment or an emergency, the clause of the “guide” can no longer apply. However, for FPSO that has the ability of self-propelled and in navigation state, it has to comply with the provisions of the "guide".

3 The coastal state has Pescod supreme power, and can conduct PSC inspection when foreign FPSO works under its jurisdiction.
In spite of this, PSC is also applicable in other cases, such as the FPSO going from one port in the country to another country for maintenance.

4 When the FPSO is not on the work position, such as in the condition of self-propelled or towage, oil discharge control requirements shall be applied. When FPSO is in work site, oil and oil-water mixture can be handled in the following measures under the permission of coastal states :

(1) to shore;

(2) burning;

(3) discharged after undertaking oil-water separation and the oil content is under 15 PPM;

(4) added to the products of production;

(5) adopting comprehensive measures mentioned.

3.1.2 Application of the provisions of the SOLAS

There is no content of FPSO in the definition of Ship of SOLAS Convention. They

are not within the scope of SOLAS Ship definition. As part of offshore oil production facilities, FPSO are " non- SOLAS vessels ".

3.2 International management practice

Generally, FPSO is not forced to register by competent authority of the international community , and follows the principle of voluntary of owners .

(l) USA : there is no FPSO in Mexico Gulf. For the FPSO that stay oversea, there is no requirement for the FPSO to hang state flag, It is on a voluntary basis of owner, such as Exxon Mobil's ZOMBA.

(2) United Kingdom : semi-submersible drilling platform and FPSO are production facilities management , they do not need to apply for the flag.

(3) Norway: there is no requirement of registration of FPSO.

(4) Australia: all the FPSO and non -propelled devices and facilities on the sea do not need to hang flag and register. （Yang ,2009）

3.3 FPSO management system of China

In June 1990, when Ministry of Transport submitted *" Regulations of the People's Republic of China Governing Survey of Ships and Offshore Installations "* to the State Council, and asked the State Council to coordinate the management of offshore oil facilities and whether floating production storage device belong to the ship, The Legislative Affairs Bureau of State Council sent a working group to visit FPSO specially. The mission agreed that after the inspection, FPSO should belong to fixed production facilities, and the competent authority of oil responsible for the management of offshore oil and gas production facilities. In August 1990, Ministry of Transport issued an official document to agree that FPSO did not register. In January 1993, in the final meeting of "*Regulations of the People's Republic of China Governing Survey of Ships and Offshore Installations"*, it further clarified the definition of offshore installations, as well as the inspection of offshore oil facilities

do not belong to "*regulations*".

At present, Safety Office of Offshore Oil Operations of State Administration of Work Safety is the competent authority of safety of FPSO(include offshore oil operations).It has issued a series of administrative regulations and standards to monitor designing, building, surveying, the production process and personnel training etc of FPSO. It also issues safety production license to FPSO in accordance with the law.

State Oceanic Administration of People's Republic of China supervises the pollution of FPSO, and it takes an route inspection on FPSO's pollution prevention management 2-3 times a year. Fixed platform and FPSO are not equipped with "oil pollution emergency plan of oil pollution " and "the garbage record Book".

The lightering of FPSO has not been supervised as lightering form Ship to Ship because it is just a corporate behavior. And there is no corresponding mandatory regulation on it. Only the internal supervision of CNOOC exists. There is no administration regulation for tanker berthing along FPSO, no train relevant provisions on the administration of files, the only specification for industry standards under the "*Operation rules for vessel berthing platform"*.

Classification Society as a trusted independent verification society, FPSO needs to have class certificate and related technical inspection certificate of Classification Society in china.

3.4 The status quo of maritime administration's surveillance on FPSO

3.4.1 The Problems exiting

At present, FPSO in China located in the Bo Hai Sea and South China Sea, Tianjin, Hebei, Shandong, Zhanjiang, Hainan MSA assume the relevant regulatory responsibilities of FPSO, the problems in the surveillance are the following:

1. Legal status of FPSO is not unified

Due to the dispute of conventions, laws and regulations on the legal status of FPSO, the surveillance of different Maritime sectors in China is verified. For example Zhanjiang MSA regards it as a ship, including it in the scope of regulation, but other MSAs do not deem it as Ship, and not within the scope of surveillance. Because of legal status of FPSO is uncertain, there is no unified surveillance of different MSA, such as: registration problem, the problem of reporting and loading of dangerous goods, the applicable rules of Safety Management System, personnel training and manning issues, statutory survey issues, emergency response plan, compensation of pollution damages and other issues.

2. Surveillance of the Maritime Administration on the FPSO is very weak, and different Maritime Administration adopts different ways, so it is difficult to form a unified standard.

The main responsibility of Maritime Administration on FPSO focuses on four areas of navigation management, Ship management, crew management and anti-pollution prevention management, but just on some aspects of base on the actual condition of the jurisdiction. Most marine sector is just limited on the lifting vessels and support vessels, and conducts no action on the supervision of FPSO, not to mention manning and training, examination, certification personnel on Board the FPSO.

3. On-site supervision is very weak. As the FPSO far from the coast, (usually more than 30 nautical miles), real-time monitoring will consume a lot of time and money, so it is hard for the vessel in service to reach the area.

3.4.2 Status quo of Dong Ying maritime supervision

Since July 2010, according to "*notice on the adjustment of maritime safety regulatory responsibilities of the Bo Hai Sea oil platform"* of the China Maritime Administration, Dong Ying Marine Department began to assume the responsibility of supervision of exploration and development of offshore oilfield of 28-2, 25-1 working area . Now, Dong Ying maritime law enforcement officers will take site supervision every time of FPSO lightering operations. The maritime supervision can be carried out limited to the following aspects:

1. No direct supervision to FPSO itself

(1) Relevant certificates FPSO hold

Two FPSO in Dong Ying area do not have *the certificate of ownerShip of Ship* and *the certificate of the nationality of the Ship*. Both have the classification certificate and relevant technical certificates issued by CCS.

(2) Manning of FPSO

Both have 2 of "mooring captain," 2 of "assistant captain", "mooring captain" hold a competency certificate issued by the maritime department, other staff on Board and production operation personnel hold the certificate of offshore safety operation training issued by CNOOC.

(3) Lightering operation of FPSO

Transport of crude oil from FPSO to shuttle tanker follow the operation procedure which formulated by CNOOC, and the company does not apply to the maritime administration for permission.

(4) Pollution prevention management of FPSO

FPSO hold the documents like *Marine environmental impact assessment report*, *oil spill emergency response plan*, garbage collection and processing and other related documents approved by ocean administration department.

According to the *discharge standard of the offshore oil development industry, oily wastewater "(GB4914-85),* FPSO discharge sewage in less than 30 PPM, and records the relevant discharge operation.

(5) Traffic safety supervision of FPSO

The maritime administration do traffic management in operation area of oilfield relies on existing VTS, and routine patrol of cruise Ship.

2. Conduct comprehensive maritime regulation on tug in working area of oilfield

3. The shuttle tanker and lightering operation are the key of the maritime supervision. And the maritime sector is responsible for on-site visa, supervion of ballast water discharge.

4. Officer of Maritime department will be on-site each time of lightering, and

supervise the whole process of operations, and strengthen each link of operation. The officer will conduct inspection on shuttle tanker and lightering operation, and the content of inspection can be seen in appendix 1 and 2 respectively.

3.4.3 The surveillance of other MSA

1 Tianjin Maritime Bureau within the jurisdiction of the maritime drilling platforms Regulated

Since 1980, Tianjin MSA has begun to supervise on the FPSO， and it has a more successful experience in surveillance of FPSO.

The headquarters of four subsidiaries of CNOOC –Tianjin Branch, Offshore Oil Engineering Co. Ltd., Oilfield Services Limited, Energy Development Co., Ltd are all located in Tianjin, and Tianjin MSA supervise the Safety Management System of the above-mentioned companies, so the communication of Both side are frequent. It is easier for Tianjin MSA to regulate on FPSO.

2 The surveillance of FPSO of Zhanjiang MSA within the jurisdiction

Platform within the jurisdiction of Zhanjiang MSA considers the FFSO as ship, and supervises the FPSO refers to the measures carried out on vessels.

Chapter 4 Risk Factors Assessment of Lightering Operation in Dong Ying sea area

This chapter mainly identifies and evaluaties the risk factors of lightering in Dong Ying sea area, then draws up a checklist of risk assessment of lightering operation of the FPSO.

4.1 Case analysis of FPSO lightering

With the large-scale of lifting tanker Ship and increasing frequency of FPSO lightering operation, there is a potential risk of FPSO lightering operation of Dong Ying. As follows:

1. On “Chang Qing” FPSO of BZ28- 1 oilfield in January 1999, when shuttle tanker "Da Qing 72" was mooring, main mooring cable fell off the chain stopper, breaking off vice wire rope. The broken vice wire hit the head of a sailor of "Da Qing 72", and the sailor died instantly. The cause of the accident until chain was improper operating of chain stopper. (Tian Jing MSA, 1999)

2. In October 2010, shuttle tanker "Li Ping Tan", in the process of berthing “Hai Yang Shi You 102” in no-load, collided with tug-“Bin Hai 266” in 3 nautical miles south of “Hai Yang Shi You 102”. The port side of tug was partically damaged. The direct cause of the accident is that the surge was so bigger that it caused the tug rock transversly, and the pilot and captain did not communicate well and responsed timely to the mutation of sea weather.（Dong Ying MSA, 2010）

3. In november 2012, FPSO "Hai Yang Shi You 102" was unloading crude oil to shuttle tanker “Ping Chi” when the oil hose broken suddenly. The marine officer on-site asked to stop the lightering immediately. The lightering work was allowed to continue after repairing the damaged pipeline. The accident belongs to poor maintenance of oil hose for transmit oil from FPSO to tanker. Fortunately the

transformation pressure in the hose was not very high, and just a small amount of oil spilled into the sea. It caused a general pollution accident. (Dong Ying MSA, 2012)

The analysis of the accident cause:

Based on the analysis of the accidents mentioned above, it's found that there are many reasons for the accident, like poor visibility, wind, flow, big surge or outburst, restricted manipulation of Ship and inherent flaws with the device itself, etc. The main cause of the accident caused by lightering operation can be attributed to the following point:

(1) FPSO collides with the assisting tug because of poor visibility, bad weather, surge and mechanical failure;

(2) FPSO or shuttle tanker collides with the passing Ship caused by the dense traffic and the influence of natural conditions like fog, wind, tide, flow;

(3)The accident like collision, touch loss, damage of cable attribute to improper operation, not properly lookout of pilot or the crew on Board;

(4) If the tanker's manipulation is limited or shifted when it is mooring , the cable connecting FPSO and tanker may be broken, and then the tanker is out of control ,and collision happens.

(5) Poor communication results in not-timely coordination.

4.2 Identification of risk factors of lightering operation

4.2.1 Definition of fault tree analysis

Fault tree analysis (FTA) is a top down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. This analysis method is mainly used in the fields of safety engineering and reliability engineering to understand how systems can fail, to identify the best ways to reduce risk or to determine (or get a feeling for) event rates of a safety accident or a particular system level (functional) failure. (Wikipedia, May 2)

4.2.2 Risk identification of accident cause of lightering water area

Accident statistics of FPSO lightering operation for many years show that although the accident is less, the consequence and impact are huge. So risk identification of the cause focuses on the accident like cable damaged, tanker out of control and collision, etc. The causes of these accidents are various, through the analysis of specific fault tree, qualitative analysis of internal relation of the cause factors of lightering operation. And find countermeasures based on it, then take preventive measures to eliminate hidden dangers, make sure the safety of lightering operation.

(1) fault tree analysis

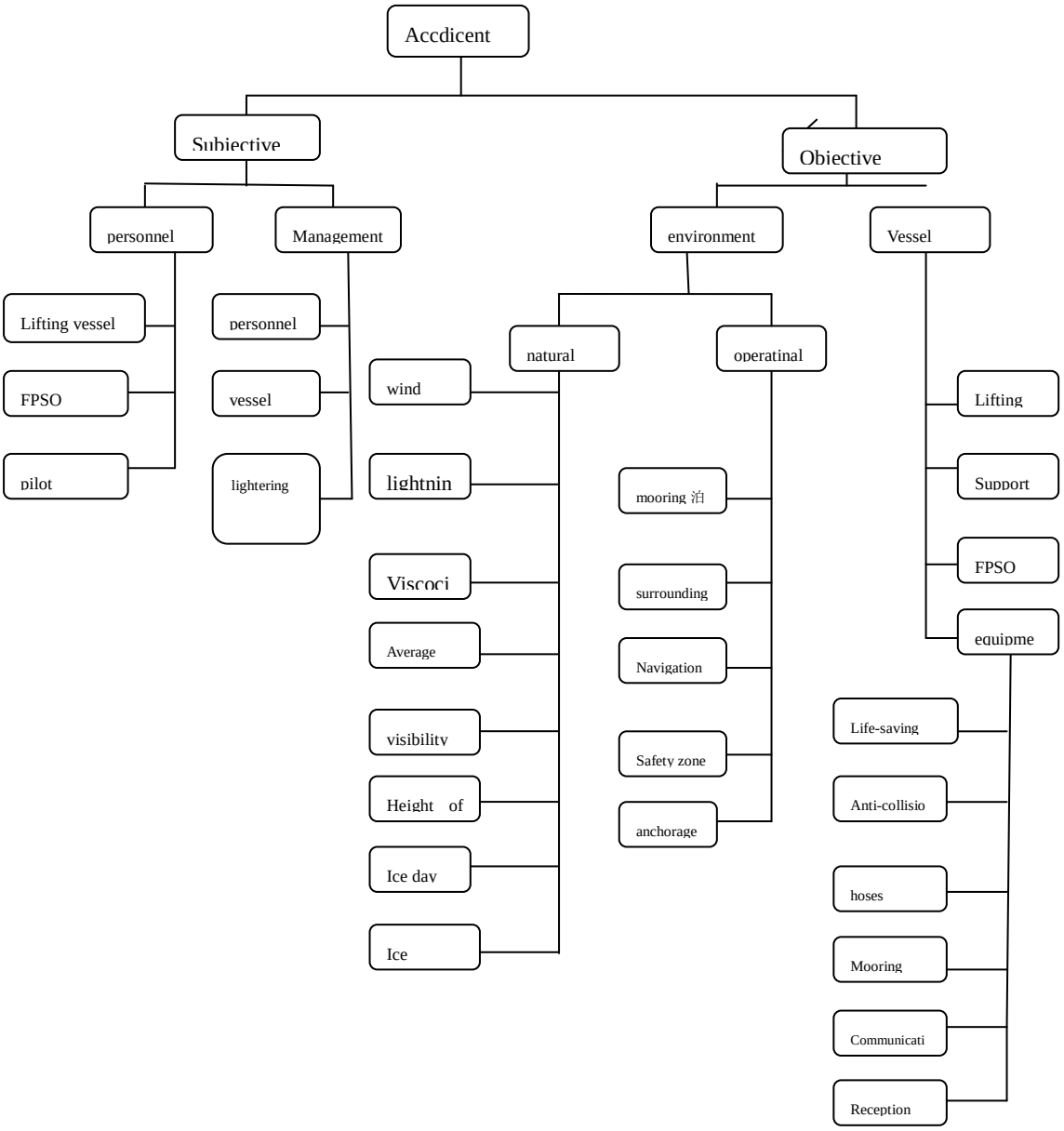


Figure 4-1 fault tree of broken cable, collision of lightering operation

Source: Compiled by author

Form the risk identification of accident cause depend on the fault tree model above, it appears the cause of accident have relationship with the factors like wind, poor visibility, thunderstorm, tide, suitable condition for mooring of FPSO, the waters

around, operational error of shuttle tanker, tug, FPSO, negligence of crew, behavior management, ship management, etc.

4.2.2 Induction of Fault tree analysis

Through fault tree analysis, the main risk of lightering operation of FPSO are as follows:

Personnel factors: inadequate emergency action; Negligence of accident alert, crew break the regulation, staff operational errors of crew, verification error of the situation, misjudgment of danger, negligence of emergency action, , negligence of lookout, take the wrong selection, etc.

Ship factors: Ship breaks the regulation, miss contacts with the tug , manipulate error of tug, the control failure of rudder, mooring operational error of mooring, etc.

environmental factor: misjudgement of the effect of wind, traffic density, misjudgement of flow velocity or change sharply, poor visibility, etc.

Management factor: no corresponding regulation, not implementing regulation properly, etc.

4.3 Risk assessment on the impact of various factors on lightering operation

4.3.1 Environmental factor

According to the practical experience of the maritime officer and operators, and by assessing the navigation environment around the work site, and the environmental factors that affects the lightering can be shown in Table 4-1:

Table 4 -1 FPSO working environment factors of risk assessment

Factor	No	Name	Degree of dangerous					Note
			lowest	Lower	normal	higher	hishest	
Natural	1	Wind						
	2	Lightning						

	3	Viscosity of flow						
	4	Average tidal						
	5	Visibility						
	6	Wave height						
	7	Average ice day						
	8	Average ice thickness						
Operational environment	9	mooring						
	10	Waters around						Include the influence of fiShing Ship,fleet
	11	Navigation aids						Lay out of navigation mark
	12	Security area						

Source: Compiled by author.

4.3.2 personnel factor

According to whether relevant personnel have pass the training of maritime department and whether the behavior is under the supervision, influence of personnel factor can be evaluated in table 4.3- 2:

Factor	No	Name	Degree of dangerous					note
			Lowest	Lower	normal	higher	highest	
Personnal	1	Crew						
	2	Worker of						

		FPSO						
	3	Related person						Pilot

Table 4-2 Risk assessment of human factor of lightering operation

Source: Compiled by author

4.3.3 Marine equipment factor

According to whether the relevant Ship and special equipment is approved by the maritime department and whether carry out on-site inspection, tanker and equipment factors can be evaluated in Table 4-3:

Table 4-3 Risk assessment of equipment factors of lightering operation

factor	No	Name		Degree of dangerous					note
				lowest	Lower	normal	higher	highest	
Vessel and equipment	1	Vessel	Lifting vessel						
	2		Tug						
	3		FPSO						
	4	Equipment	Life-saving equipment						
	5		Anti-collision equipment						
	6		Oil hoses						
	7		Mooring equipment						
	8		Communication equipment						
	9		Loading equipment						

Source: Compiled by author.

4.3.4 Management factor

Based on whether have relevant system and whether maritime department have carry out inspection on the implementation of regulation, we got Table 4- 4:

Table 4-4 Management factors of lightering management of FPSO

Factor	No	Name		Degree of dangerour					Note
				Lowest	lower	normal	higher	highest	
Management	1	Worker of FPSO	training						
	2		Surveillance						
	3	Equipment Management	Rules						
	4		Surveillance						
	5	navigation management	Regulation						
	6		Surveillance						

Source: Compiled by author.

4.3.5 Establishment of risk assessment table of lightering operation

Based on the above analysis, and in combination lightering operation constraints of section 4.3, a risk assessment checklist of lightering operation can be compiled.(details in appendix 3)

Chapter 5 Research on Related Issues of FPSO Lightering Operation in Dong Ying sea area

This chapter researches on the limitation condition and operation plan of lightering operation of FPSO in Dong Ying sea area.

5.1 Equipment of lightering operation of FPSO

In order to ensure the safety of the lightering, FPSO should be equipped with safety equipment according to the lightering requirement and approved by the competent authority. Shuttle tanker should also be equipped with corresponding equipments and fittings in compliance with the requirement. Equipment to ensure safety of lightering and berth or mooring should include anti-collision devise, oil hose and equipment for mooring, etc. (Liu, 2004, P30).

For the safety of mooring and unmooring and safety of transfer, before arrival, lifting vessel master must contact the loading master about the Notice of Readiness (NOR), and ensure the effectiveness and compatibility of fittings.

5.1.1 Anti-collision equipment

During lightering operation accidents, such as encountering bad weather like squall line, the support can not play the role, and the lifting vessel may crash into the FPSO. So anti-collision equipment should be equipped, like the fender. The fender used should be adapted to the requirements of absorbing energy and recovery, and can satisfy the criteria for not making the upper structure of hull contact.

5.1.2 Oil hoses

Oil hoses are transfer channels which connect FPSO and lifting tanker. It is the critical safety equipment for lightering, and the connection and disconnection of it are

the key link of operation. Oil hoses are provided by the FPSO, and it should be checked each time for hydraulic pressure test record and any other defects.

Figure 5-1 Oil hoses

Source: China National offshore oil Corporation Tianjing company(2010), The introduction of FPSO. Unpublished PPT , Tianjing, China.

5.1.3 Mooring equipment

Offshore oil transfer operations, FPSO and lifting vessel shall be connected with the corresponding mooring equipment during lightering operation. The reliability of mooring cable, winch and deck machinery are very important issues for the safety of lightering. Both sides should do mooring scheme in advance, so that cable can be connected quickly, and make sure that chain braker and cable are in safety state.

(l) Hawser

The mooring hawser is towed by support tug to lifting vessel through messenger line, the hawser and messenger should be provided by the FPSO, and FPSO should have spare parts about them.

Figure 5-2 Hawser

Source: China National offshore oil Corporation Tianjing company(2010), The Introduction of FPSO. Unpublished PPT, Tianjing, China.

Figure 5-3 Hawser and messenger line

Source: China National offshore oil Corporation Tianjing company(2010), The introduction of FPSO. Unpublished PPT, Tianjing, China.

(2) Pick up line and throwing line

Throwing line and pick up line should choose material that can float, and FPSO shall equipped with a sufficient number of line.

(3) Bollard

The Bollard should have sufficient strength. The choosen Bollard and fairlead should aligned when mooring. (CNOOC, 2009)

5.2 FPSO lightering operation constraints

By sorting out two oil terminal regulation, combine with relevant laws and regulations, industry standards, as well as the practical Ship maneuvering and sailing experience of pilot and crew sea weather conditions, the limit of operation are:

The FPSO heading may restrict the lifting vessel approach heading due to the proximity of WHPs (Well Head Platform). Closest approach to WHPs must be not less than 500 meters. Certain FPSO headings may dictate that mooring be delayed where the lifting vessel approach heading would constitute an increase in risk of collision with a WHP. On completion of loading, it may, at times also prudent to leave the lifting vessel connected when FPSO heading would make the risk of collision unacceptable if unmooring were to take place.

The following are the responsibilities of the Pilot/Loading Master and the Master of the Lifting vessel.

5.2.1 Night Operations

Mooring operations will not normally be conducted at night unless the Pilot and Lifting vessel Master agree that it is safe and practicable to do so. Nighttime shall be

deemed to be outside the period 0600to three hours before sunset. For all operations conducted during the hours of darkness, sufficient illumination must be provided to allow the activities to be conducted safely. This illumination to include over side to monitor for oil leaks. Unmooring may be carried out any time.

5.2 .2Visibility

Mooring or unmooring should not commence unless the visibility is greater than 1 mile. If visibility reduces during offloading, the operation may continue provide safety and environmental protection are not compromised. When mooring in conditions of reduced visibility, the lifting vessel should make optimum use of all navigational aids available, including radar, rangefinder and radio advice and assistance from the support vessels. However, in circumstances where a failure of any instrument would render the operation hazardous, no attempt is to be made to approach the FPSO until conditions improve.

5.2.3 Operating Criteria

The operating criteria give the following indications:

When the Wind Speed< 13.9 m/s, and the Wave Height < 2.5 m, the approaching and berthing operation can be carried out normally;

When the Wind Speed> 13.9 m/s and < 17.1 m/s, or the Wave Height > 2.5 m and < 3.0m, the approaching and berthing operation should be suspended . If the lifting vessel has already moored to FPSO, whether she should stay at the berth depends on the Loading Master/pilot and lifting vessel's Master decision agreed together;

When the Wind Speed > 17.1 m/s, or the Wave Height > 3.0 m, the lifting vessel must be disconnected from FPSO and the terminal will be closed to the lifting vessel.

5.2.4 Extreme Hawser Tension

Hawser tension is measured by a load cell on the FPSO mooring winch with read outs in the FPSO control cabin and CCR. The Offloading Supervisor is to ensure that the hawser tension is monitored throughout the operation.

To safeguard the FPSO structure, a weak link is incorporated in the chafing chain connection, preset to fail at a tension of 300 Tonnes.

All loads in excess of 100 Tonnes should be reported immediately by the Offloading Supervisor to the Loading Master, Pilot and Lifting vessel Master on the lifting vessel and recorded in the loading log. Cargo operations will be suspended and preparations made for disconnection and departure if peak loads in excess of 125 Tonnes occur with a frequency of 2in 30 minutes or the weather is forecasted to worsen the lifting vessel will depart from the berth.

5.2.5 Normal Operating Conditions

In the moored position, a nominal tension should always be maintained on the hawser. This will serve to maintain adequate clearance between lifting vessel and FPSO. It will also serve to reduce surge stresses on the mooring assembly and give directional stability to the lifting vessel to ensure alignment with the FPSO.

While the lifting vessel is moored, a support vessel will act as a stern tug for this purpose. If during normal operations a difference of 15^0 in heading occurs between the lifting vessel and the FPSO, the support vessel will be requested to take the appropriate action to recover alignment. If this mis-alignment approaches 30^0, loading will be stopped and disconnection may be considered.

5.2.6 Maximum Operating Conditions

The Loading Master/Pilot should be advised of all high tensions recorded in excess of 100 Tonnes. Remaining on the berth and continuing loading will depend on maintaining an ability to affect a controlled release of the hose and hawser. Given that mooring equipment is in good order, the lifting vessel will be unmoored before hawser loads reach 125 Tonnes twice in a 30 minute period. When weather conditions are obviously deteriorating there should be no delay in leaving the berth.

5.2.7 Surveillance of Hawser

The mooring hawser should be kept under continued visual observation. If any visible

signs of chafing or fraying becomes apparent, this must be reported to the Pilot, Loading Master and offloading Supervisor, and cargo loading must be stopped immediately. If considered necessary after further examination, the lifting vessel may be required to leave the berth until a new hawser is fitted.

5.2.8 Surveillance of Hose

The offloading hose should be kept under regular visual observation. If any visible signs of chafing, or leak becomes apparent, this must be reported to the Loading Master and Offloading Supervisor, and cargo loading must be stopped immediately . If deemed necessary by further examination, the lifting vessel may be required to leave the berth until a new hose section is fitted.

（CNOOC, 2013）

5.2.9 Personnel

Personnel of lightering must go through the corresponding professional training. They can communicate and contact with each other effectively in operation; personnel on duty shall pay close attention to the weather and sea condition, when the weather turns bad or the sea swell up, they shall notify the lifting captain.

5.2.10. Vessel

1. Lifting vessel

The age of lifting vessel generally should not be more than 15 years, or else it should get the approval to engage in lightering operation. Foreign liquid vessel that is over 20 years of shall not be allowed to engaged in lightering operations into China waters.

2. Support vessel

Two support vessels are available to assist a lifting vessel mooring, loading and unmooring. The largest of these vessels has a Bollard pull of 70 tones. One of these will act as a stern tug throughout the loading operation while the lifting vessel is moored to the FPSO.

Figure 5-4 Tug on duty arriving at platform

Source: China National offshore oil Corporation Tianjing company(2010), The introduction of FPSO. Unpublished PPT, Tianjing, China.

5.2.11 Equipment

Mooring equipment should be able to meet the requirements for safety berthing of the ship, and the type and the scale of vessel should be regulated according to the specification of equipment.

5.3 Lightering operation plan of FPSO

According to the characteristics of the FPSO and lightering operation, combined with environment, personnel, Ship and equipment factors, formulating the related technical standard and operating procedure is the effective way to slove the problems of multiple-aspect management, and multi-sector collaborate. Safety responsibility is not clear of offshore oil field.

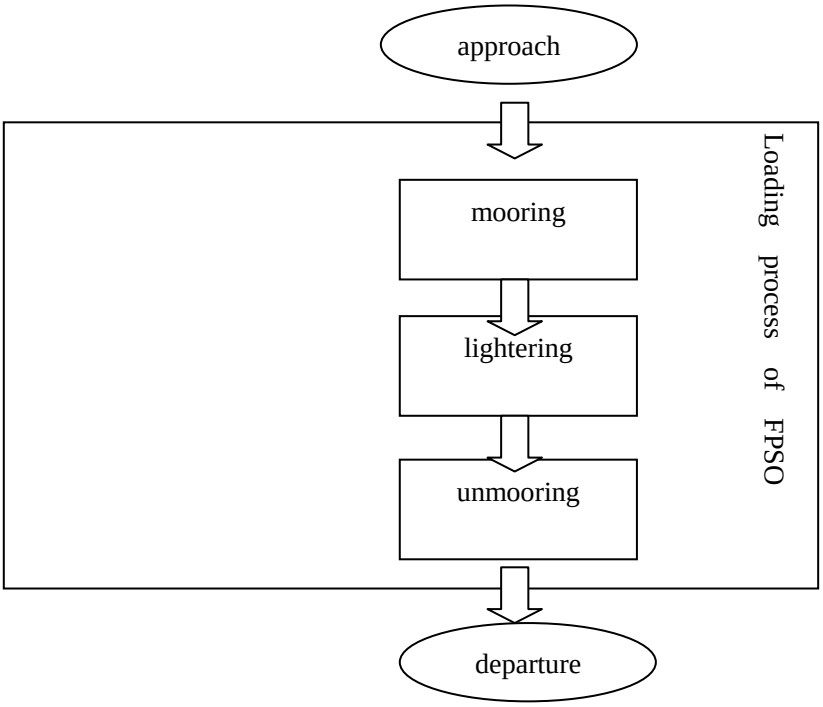


Figure 5-5 FPSO lightering operation

Source: Compiled by author.

5.3.1 Arrival of lifting vessel

Master of lifting tanker shall notify the FPSO 72h, 48h, 24h, 12h separately before arriving at the designated waiting area aBout the expected time of arrival. If the lifting tankers depart from the last port and estimated arrival time is less than 72 h, then captain of lifting vessel should send the expected arrival time just after the departure.

5.3.2 Preparation before operation

Before the mooring operation, the FPSO and lifting tanker should be appropriately prepared, including test and safety inspection of cargo equipment, etc.

1. Make sure the communication between the FPSO and tanker meets the requirements.

2. Preparation of tanker and FPSO

Before the mooring, the FPSO and lifting tanker make the following preparations:

(1) research on the operating procedures and instructions by the shipowner as a supplement;

(2) ensure that the crew familiar with operating procedures, especially the mooring and unmooring procedures;

(3) make a good inspection;

(4) the main engine, steering gear, and all the navigation and communications equipment shall be in the normal state;

(5) avoid heeling, no obstacle around lifting tanker;

(6) get ready the disassembling device for oil hose;

(7) receive the weather forecast;

(8) check the fender and mooring equipment;

(9) get ready for fire fighting and anti-pollution equipment;

(10) loading master and offloading supervisor of FPSO supervision shall determine the time of lightering operation, mooring scheme, etc on the basis of weather and tide condition;

(11) the emergency response plan shall be compiled, and agreed by two side

The crew of both side shall be familiar with the respective position and responsibilities in the event of emergency situations;

(12) before commence for mooring, the lifting vessel and FPSO shall confirm the security check has been completed, the operating procedure is right, no abnormal situation occur;

(13) messenger line and pick up line shall be connected with the hawser;

(14) soot blowing of Boiler ash shall be carried out before the lightering.

3. Navigation signal

When approaching FPSO within 3 miles , the lifting tanker shall show the navigational lights or shapes for a vessel restricted in its ability to maneuver on its approach to, and on leaving the FPSO as as specify by "international regulations for preventing collisions at sea 1972".

While moored, lifting vessel shall exhibit lights and shapes in accordance with the "*International regulations for preventing collisions at sea 1972"*.

5.3.3 Mooring and oil hose connection

1 Approach direction of lifting vessel

The Pilot will advise the approach direction after ascertaining from support vessels that the messenger and leader lines have been streamed out downwind from the FPSO. The 2nd support vessel will control these lines. The Offloading Supervisor will advise the Pilot of the FPSO heading and the historical swing pattern of the FPSO over the preceding 3 hours.(CNOOC, 2012)

2 Speed of approach

Lifting vessel shall slowdown after entering the waiting area and must get ready for arrival, and its time for reduce speed depends on the specific situation. Normally, lifting vessel should slowdown 10 nmiles away from FPSO, and then proceed toward it in a slow speed. (Pan 2005, p10)

Table 5-1 the state of lifting vessel when it approaching FPSO

Remaining distance from the FPSO	10′	5′	3′	1′	Downwind 300-400m
Speed and action of FPSO	-	5kn	4kn,connect with the stern tug	2kn,confirmation of mooring	0.5kn,receive pick up line

Source: compiled by author base on the unpulished paper of CNOOC

3. Mooring

Support vessel transfers the end of the pick up line to the Bow of lifting vessel. Then crew on Board the lifting vessel pulls on Board the pick up line, tag line and the end of the messenger then connected to the deck winch. Pilot adjusts the position according to the report of chief officer of warping. The FPSO continues to deploy the messenger and hawser till the hawser handling winch is in the fully deployed position. Concurrent with this, the lifting vessel continues to winch in the messenger till the chaff chain enters the fairlead. The lifting vessel continues to winch in the messenger

till the chaff chain is locked in the chain stopper (at the time, the Bow of tanker is 80 meters from the FPSO). After the connection of hawser, stern tug begins to apply sufficient pull to maintain the lifting tanker and FPSO aligned. Central control room of FPSO is equipped with tension meter, which displays the tension of the hawser in real-time, through the communication of the offloading supervisor, loading master and pilot, they all know the tension of the hawser in time. When changing tidal steam or wind direction, the stern tug can adjust the pull on the stern of lifting vessel under the direct of pilot. (Wang, 2004,p13)

4. Connection of oil hoses

The hose will be transferred from the FPSO to support tug, then the end of the hose string will be transferred to the lifting vessel's starboard midship manifold by the support tug. Lifting vessel's derrick/crane then lifts the hose during the lightering. The loading master will direct the crew of lifting vessel to connect the hose. The method of hose connection is to conform to OCIMF recommendations contained in the Single Point Mooring Maintenance and Operations Guide. The hose shall be fully deployed from the FPSO to ensure there is sufficient slack in the hose to prevent over stressing the hose.

Figure 5-7 Diagram of loading hoses connection

Source: China National offshore oil Corporation Tianjing company(2010), The introduction of FPSO. Unpublished PPT, Tianjing, China.

5. Precautions

Although the pilot, loading master, lifting vessel master all have abundant practical experience, the following points should be pay attention to:

(l) lifting vessel shall approach FPSO in downwind or downflow direction ;

(2) two support vessel shall be used for mooring.

(3) when two sides agreed on the mooring plan, consideration shall be given to the convenient of departure;

(4) the loading master and offloading supervisor of FPSO shall always be ready to suspend the cargo loading in situations like worsening weather leading to unacceptable hull stresses or failure of equipment on FPSO or lifting vessel requiring repairs before loading can continue. The decision to suspend the operation shall be the time is enough, and the situation is still in control of the state, two ship their actions should immediately inform the other party; the decision to disconnect shall be made in time for normal procedures to be followed and an emergency disconnection should be avoided whenever such a possibility can be foreseen.

(5) Both side of lightering shall always have the responsibility of lookout;

(6) in the process of mooring, support vessels shall always be available for escort duties

.

5.3.4 Cargo loading

Figure 5-8 Lightering operation

Source: China National offshore oil Corporation Tianjing company(2010), The introduction of FPSO. Unpublished PPT , Tianjing, China.

1. Ballast

All ballast discharged into the sea must be cleared and with no oily residues, and the lifting vessel shall have segregated ballast tanks. Ballast of lifting vessel must be sufficient so that it can get a reasonable trim. When the propeller well submerged, the bow thruster should be at an effective depth to ensure the lifting vessel in optimum maneuverability during pick up and mooring ,and can depart at any stage of the lightering.

All movements of loading cargo and discharging of ballast must be pre-calculated on board the lifting vessel before connection to ensure the lifting vessel within acceptable margins of stress and stability at all intermediate and final stages of offloading.(CNOOC, 2013)

Sometimes if the discharging of ballast is delayed, the combined weight of oil and

water ballast exceeds the permitted load line even for a short time, and loading should be stopped for a reasonable trim irrespective of weather condition.

2 Watch-keeping duties and continuous inspection

The Lifting vessel's bridge must be manned at all times by a responsible Officer, for continuous surveillance of the mooring and hose connection.

During the process of mooring and hoses connection, the bridge of the lifting vessel must be manned to watch the operations.

During loading operations, the Loading Master and Pilot shall ensure that the following checks are being carried out on a continuous basis.

1 Confirm with the Offloading Supervisor that the peak Bow hawser tensions are within the acceptable limits.

2 Confirm that there is suitable pull by the stern tug to provide a stable moor.

3 Inspect the immediate area of the lifting vessel and the loading hose for any signs of oil spillage or leakage.

4 Inspect the mooring line regularly throughout its visible length.

5 Inspect the hose for chafe, damage or leak. (CNOOC, 2013)

3 Surveillance of Hawser

The mooring hawser shall be kept under continued visual observation. Lifting vessel gives FPSO 1 hour's notice of completion of loading. During the loading, the hawser shall be under continued visual surveillance to ensure the tension is in normal condition. Loading Master and Offloading Supervisor should be informed immediately if any visible signs of chafing or fraying has been detected, and lightering operation must be stopped immediately. The lifting vessel shall depart from the berth until a new hawser is fitted if a further inspection is needed. The main measurement of the mooring line force is through in FPSO mooring tension meter, train in the middle of the FPSO's train control room to read. Hawser tension is measured by There is a load cell on the FPSO mooring winch which can measure the tension of hawser, and can be read out in the FPSO control cabin and CCR.

4 Residential area and safe passage

During the loading, all the door of residential area should always remain closed, only

permits provide safe passage for the necessary personnel between lifting vessel and FPSO.

5 Radio

During lightering operation, it is dangerous to use radio equipment on Board. When doubt about existing of flammable gases or grounding of derrick equipments and devices, radio equipments are not allowed to be used. Low power VHF won't produce the potential danger, transmitting antenna of lifting vessel shall be grounded, otherwise it is not permitted to be used in mooring.

6 Radar

Lifting vessel and FPSO communicate in advance before using radar during lightering operation, it is same to support vessels.

7 Other vessel

During the whole process of lightering operation, vessels without permission shall not berth alongside the lifting vessel or FPSO.

8 Emergency response

In the event of any emergency occurring on either the FPSO or the lifting vessel, the Emergency response plans for the FPSO and the lifting vessel will be implemented and actions taken in line with these plans to bring the emergency under control. The overriding factors will always be the safety of people, limit plant damage and protection of the environment. The crew of Lifting vessel and FPSO shall always in the ready state to cope with a possible emergency situation at any time. When any contingency happens on either lifting vessel or FPSO, the emergency response plan shall be implemented and action should be taken immediately according to the plan to bring the condition under control. The safety of people, limit plant damage and protection of environment are always the most important factors taken into consideration for contingency response.

9 Smoking and naked fire

During lightering operation, the regulation about the smoking and usage of naked fire must be strictly implemented. And at the same time it shall be in accordance with the requirements of the *"international safety guide for oil tanker and terminal "*, and

displays a warning post and specify the smoking room.

In fact, most guidances are taken from *"international safety guide for oil tanker and terminal"* on general matters of safety and pollution. All lifting vessels berthed at the FPSO must conduct cargo operations in compliance with the guidance contained in it. After all the preparations, check all kinds of valve is in normal condition of open or closed, loading master informs the offloading supervisor that lifting vessel "ready to receive cargo", offloading supervisor confirms that all offloading preparations are completed and then informs the lifting vessel that pump starts.

Cargo loading must start slowly, after been confirmation that cargo is being received on lifting vessel and then loading rate can be increased to the agreed maximum

5.3.5 Departure

1 Completing the lightering

The Offloading Supervisor will oversee the whole course of lightering operation, and estimates the time of completing during the final two hours. Lifting vessel shall give formal notice to the Offloading Supervisor at 30 minutes and 10 minutes before completion. If lifting vessel needs a lower loading rate, loading master must call for a reduction, and Offloading Supervisor will respond and gradually reduce the offloading rate to the extent requested until loading is complete.(Sun 2010, p24)

2 Disconnection of hoses

When the lightering is completed, flushing shall be carried out by FPSO. the whole process of disconnection is under the surveillance of lo loading master. After disconnection, hoses shall be towed away by support tug and be recovered by the FPSO.

3 Departure

After the disconnection of hose, chafing chain will be released under supervision of the pilot, and the messenger and leader line will be withdrawn by FPSO as the lifting vessel moves astern. when lifting vessel departs from FPSO, the stern tug shall be

released after there is no risk of collision. Normally, Cargo documentation and samples will be prepared later after departure and be sent to the Lifting vessel by support vessel. The lifting vessel wait in waiting area if documentation can not be delivered timely.

4 Early disconnection

The Lifting vessel Master may, in consultation with the Pilot and Loading Master, initiate an early disconnection in situations such as:

1 Worsening weather leading to unacceptable hull stresses.

2 Failure of equipment on FPSO or lifting vessel requiring repairs before loading can continue.

The lifting vessel shall follow the normal disconnection procedure as closely as possible. It is necessary to take the decision to disconnect in time for normal procedures to be followed and avoid having to make an emergency disconnection whenever such a possibility can be foreseen.(CNOOC, 2013)

5 After Early Disconnection

If the early disconnection happens, the lifting vessel shall procced to the waiting area, and after circumstances permitted, it shall approach the FPSO again to load the spare cargo of FPSO.

5.4 Countermeasures of supervision of Dong Ying MSA on FPSO

Maritime sector shall perform their duty effectively and initiatively, and try to includ the FPSO within the scope of regulation, supervision the anti-pollution, mooring and unmooring and lightering operation of the FPSO. The specific measures are as follows:

5.4.1 Continue to communicate with the State Council, straightening out platform,

FPSO regulatory permission problems, train the FPSO oil unloading operation according to the craft operation train as early as possible to regulate; Continue to communicate with the Legislative Affairs Office of the State Council, rationalize the system of regulatory authority of FPSO, regulate the offloading of FPSO in accordance with requirement of lightering as soon as possible.

5.4.2 Maritime sector should introduce a unified regulatory guidelines for FPSO in accordance with the related guidelines of international conventions, combined with China's specific national conditions.

5.4.3 There are risks for the lightering of FPSO, before proceeding related lightering operations. If necessary, the competent authorities shall organize relevant departments to conduct a risk assessment of lightering operations, identify sources of risk, predict the probability and consequences of the accident, identify relevant risk control approach. Operator participates in lightering operation of FPSO shall establish emergency response system. The system shall consult the relevant work standards. Specifics include emergency plan, emergency signal, emergency situations, and for some emergency case handling measures, etc. operators and vessels involved in lightering operations of FPSO shall establish relevant emergency response system which shall refer to the relevant operating standards above, and contains contingency plans, emergency signals, emergency situations as well as some emergency measures to deal with the situation and so on.

5.4.4 In the specific requirement of regulation, the maritime sector shall delineate specific lightering area, lightering practices and natural conditions, and also study how to surveillance the ballast water during lightering, and then formulate a regulatory guidelines for the jurisdiction according to the specific terms and other relevant provisions of the amendment of Annex I of the MARPOL Convention and relevant national regulations of lightering, combined with the specific circumstances of jurisdiction and " guideline of lightering operations (petroleum)". "the specific

content of the waters of the area such as how to carry out the above-mentioned problems of the area suitable for the formation of the specific circumstances of the waters lightering regulations to the provisions of the approved transfer operations in the region as a specific basis.

5.4.5 In terms of the specific regulations, maritime sector is according to the related management regulations of the state regulatory guidelines and industry standards, according to the convention supplement the terms of the new chapter 8 amendments convention and other relevant provisions, and combining with the jurisdiction over the waters of the specific conditions and the craft operation guideline (oil) of the specific content.

5.4.6 Our maritime authorities in the daily supervision of the lightering, in addition to the above requirements, maritime authorities should attach great importance to cultivation of the senior commanders of lightering to ensure the safety navigation environment of lightering area. Ensure the navigation environment of the area, etc. In addition, marine sector should strengthen the management of illegal lightering operation and establish mechanism of claim for compensation of oil pollution, increasing the propaganda of conventions, laws and regulation, reinforce the training of personnel. (Wu, 2010)

Chapter 6 Conclusion

The paper takes the FPSO lightering operation in Dong Ying Sea as the object, researches on the specification regulation for the FPSO lightering operation based on the analysis of two regulations of FPSO terminal in jurisdiction and technical standards in China and abroad. The main conclusions are :

6.1 It combines the cases of accident in jurisdiction, applies the theory of fault tree to identify the risk factors of FPSO lightering operation, evaluates them, and develops a risk assessment checklist of lightering;

6.2 It analyzes and formulates the operation constraints in Dong Ying sea area, and optimizes the working procedure;

6.3 It analyzes of the problems existing in marine surveillance of FPSO, and puts forward suggestions for future work.

The research enriches the understanding of risk factors and procedure of FPSO lightering operation to a certain extent, risk and the theory of FPSO lightering operation, and provides some ideas for the maritime supervision of lightering of FPSO and comprehensive protection against operating risk.

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Appendix A Checklist of surveillance on lifting vessel

Time		visibility		Start time	
Oilfield		Wind speed		Max loading rate(M3/H)	
FPSO				Output amount	
Lifting Vessel		pilot		Expected unmooring time	
Flash point			Temperature of cargo		

Item	Y	N
1、Whether weather and sea conditions meet operational requirements of lightering?		
2、Whether lifting vessel's equipment and personnel meet requirements for loading?		
3、Whether the necessary safety and pollution prevention information and documentation have been exchanged between the tanker and FPSO?		
4、Whether support vessels meet the requirement for mooring, loading and unmooring?		
5、Whether the contact way has been identified when radio contact been interrupt?		
6、Whether the defects of security check of lifting oil have been corrected?		
7、Whether all relevant items of Ship/shore checklist has been checked and meets the requirements of lightering operation?		
8、are there adequate lighting to ensure effective visual surveillance of moorings, oil hoses and equipment around the Ship?		
9、whether the agreed emergency stop procedures of lightering has been agreed and personnel to fully understand by related personnel?		
10、Whether emergency escape plan has been clearly defined and prepared, and all persons on Board fully understand?		
11、Whether emergency towing wires correctly positioned?		

12、Whether personal on duty familiar with the lightering ?		
13、whether the vessel the process loading has been agreed between lifting vessel and FPSO?		
14、Are all cargo tank at positive pressure with an oxygen content of 8% or less by volume?		

Signature: _____ Signature: _____

Capt. or C/Off of Lifting Vessel Loading Master

Appendix B Checklist of Surveillance on FPSO's Lightering Operation

Name		Nationality		FPSO			
emergency response plan		the implementation of Ship/shore safety checklist					
Crew are familiar with the emergency response plan		vessel meets the requirements of offloading of FPSO					
Whether technical information of safe operation of cargo, ballast water and sewage tanks are complete?							
Whether the lightering in accordance with the approved loading plan?							
Whether cargo hoses been tested routinely and cetified?							
Name of support vessel		cooperation of pilot, master of support vessels and lifting vessel					
Mooring							
Weather		Sea condition					
Whether the mooring procure is in normal condition		the cooperation of pilot, master of support vessels and lifting vessel					
Lightering							
the loading procedure is in normal condition							
Duty and communication							
Unmooring							
Weather							
unmooring procedure is in normal condition							

Cooperation of pilot, master of support vessels and master of lifting vessels	
Report	

Appendix C Risk factors Assessment Checklist of FPSO Lightering in Dong Ying Sea area

Name of vessel		Nationality	
FPSO		Time	

Natural condition		Danger index	
		High	Low
Wind speed	less than 6 or equal to		
Visibility	greater than or equal to 1 nmile		
Lightning	Whether lightning storms or other inclement weather is nearby of FPSO		
Flow	The maximum surface velocity exceeds 2.5kn		
Wave	Maximum wave height exceeds 2.5M		
Ice	Whether there is a continuous piece, and ice thickness exceeding 10cm		
Obstacle	Are there obstacles within the 1000m scope l000m of operation		
Human factors			
Mental state	Whether worker fatigue?		
Health	Whether workers have sudden illness		
Technical level	Whether they hold the relevant qualifications and whether familiar with operation		
Vessel			
Support vessel	Whether support vessels re available?		
	Whether master of support vessel have relevant work experiences?		
	Whether maneuvering device is in normal state?		
Lifting vessel	Communications and navigation equipment is in a normal state		

	Mooring equipment is in a normal state?		
	Whether maneuvering device is in normal state		
Equipment of terminal			
Oil hoses	Whether has been checked and in a normal state?		
Hawser	Are in a available condition?		
Cable	Are in a available condition?		
Bollards	Are available in a normal state?		
Communication	Whether communication is available?		
Standby equipment	Whether standby equipments are available?		
emergency response plan			
contingency plan	whether tug, lifting tanker and FPSO has established a contingency plans in detail		
Duty	Whether personnel familiar with the contents of plans and responsibilities		
Risk factors assessment conclusion			